National Transportation Safety Board
Washington, D.C. 20594

July 23, 2008

Pipeline Accident – Near Carmichael, Mississippi

In-Line Inspection Group's Factual Report

Accident Identification:

Location: Near Carmichael, Mississippi.

Date: November 1, 2007.

Time: Approximately 10:35 a.m. Central Daylight Time.

Product: Liquid Propane.

Accident No.: DCA08MP001.

Group Chair: Ravindra. M. Chhatre.

Parties To The Investigation:

Carmen R. Seal Pipeline Integrity Engineer Dixie Pipeline Company 1100 Louisiana St, Houston TX 77002	Geoff Foreman Global ILI sales leader GE Oil & Gas - PII Pipeline Solutions 1003 - 11th Street SW Calgary, AB T2R 1G2, Canada.
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Brief Narrative Of The Accident:

On November 1, 2007, at about 10:35:02 a.m. Central Daylight time, a 12-inch diameter pipeline operated by Dixie Pipeline Company was transporting liquid propane at about 1405 psig when it ruptured in a rural area near Carmichael, Mississippi. Upon being released to the lower pressure of the atmosphere, the liquid propane changed to gas. The resulting gas cloud expanded over nearby homes and ignited as a large fireball, which was heard and seen from miles away. The ensuing fire resulted in the death of 2 people, 7 people with minor injuries, destruction of four homes, damage to several other homes, evacuation of 60 families, and a burned area of about 71.4 acres of mostly grassland/woodland. Approximately 10,253 barrels (430,500 gallons) of propane were ultimately released.

Inspections Prior To The Accident:

The 1984 Hydrostatic Tests:

The joint of pipe (pipe-joint) that ruptured on November 1, 2007, was approximately 52 feet long and was located in the 12-inch piggable pipeline segment between Hattiesburg, Mississippi, and Demopolis, Alabama (Hattiesburg-to-Demopolis segment).

Dixie stated that prior to various In-Line Inspections (ILI) the Hattiesburg-to-Demopolis segment was hydrostatically tested in two separate sections. The Hattiesburg-to-Carmichael section was tested at 1854 psig for 4 hours in 1984. The hydrostatic test (hydro-test) resulted in 7 longitudinal seam-related failures and one field weld seep. The Carmichael-to-Demopolis section was tested at 1912 psig for 4 hours in 1984, and the test resulted in 8 longitudinal seam-related failures. All failed pipe-joints were replaced. Dixie stated that the pipe-joint that ruptured on November 1, 2007, (ruptured pipe-joint) had not failed or been replaced during the 1984 hydro-test.

The 1998 Tuboscope Metal Loss Inspection:

Tuboscope Vetco Pipeline Services, Inc., (Tuboscope) conducted an initial ILI inspection of the Hattiesburg-to-Demopolis segment on May 19, 1998, using a Linalog Plus standard resolution[1] axial magnetic flux leakage (MFL) metal loss tool. Dixie stated that the objective of this inspection was to evaluate metal loss in the pipeline caused by corrosion.

Tuboscope reported that typical accuracy for the inspection was +/- 15% of nominal wall thickness, and used five categories to describe metal loss anomalies**.** Tuboscope reported metal loss between 20 to 30 percent of the wall thickness of the pipe as Grade 1, between 30 to 40 percent of the wall thickness of the pipe as Grade 2, between 40 to 50 percent of

[1] According to NACE International Publication 35100, "In-Line Nondestructive Inspection of Pipelines," typical standard-resolution magnetic flux leakage tools have limited detection capability upstream and downstream from girth welds.

the wall thickness of the pipe as Grade 3, between 50 to 60 percent of the wall thickness of the pipe as Grade 4, and over 60 percent of the wall thickness of the pipe as Grade 5. Tuboscope reported a total of 32 anomalies in 28 pipe-joints in approximately 120 mile-long Hattiesburg-to-Demopolis segment (>10,560 standard pipe-joints, each 60' long). No verification digs were performed while Tuboscope personnel were on the location.

Three of the anomalies reported by Tuboscope were excavated and appropriate corrective actions (e.g., repair, replace, recoat) were taken in July/August, 1998.

No corrective actions were deemed necessary on the remaining anomalies by Dixie at that time, and none were taken.

In the Tuboscope report flaw D14, wheel count 301200 was located upstream of the ruptured pipe-joint and Flaw D15, wheel 310633 was located downstream of the ruptured pipe-joint. Wheel counts from 309090 to 309142 in Tuboscope report were associated with the ruptured pipe-joint. Tuboscope reported no anomalies between Grade 1 through 5, in the ruptured pipe-joint.

(Applicable Attachments: Appendix I and Appendix II)

The 2005 GE PII UltraScan Inspection:

Dixie contracted GE PII (GE) to conduct an In-Line inspection of the Hattiesburg-to-Demopolis segment using GE UltraScan™ crack detection tool. Dixie's reasons for selecting In-Line inspection versus hydro testing were not given, and Dixie stated that the assessment method selection process in their Integrity Management Plan did not require any additional analysis or documentation of the assessment method selection process. The inspection was conducted in two runs. The first run was conducted between June 29 and July 1, 2005, and the second run was conducted between August 2 and 4, 2005. The inspection was conducted to detect and size axially oriented crack-like anomalies in the pipe, such as fatigue cracks, areas with a lack of fusion, hook cracks, etc. Dixie stated that from the vendors they investigated, GE was the only company at that time that had an ultrasonic crack detection tool (crack detection tool) that could carry out an inspection in a liquid propane pipeline.

The crack detection tool used a 45^0 shear waves ultrasound technique. The tool could detect anomalies ≥ 0.039" (1 mm) deep and ≥ 0.984" (25 mm) long with an 85% probability of detection. Deeper anomalies, up to ~ 40% or more wall thickness deep, if less than 0.98" long may not be detected by the tool.

Anomalies, such as porosity, stress corrosion cracks, fatigue cracks, etc., in the circumferential girth welds could not be detected using this tool. However, the tool could detect axial defects, such as areas with a lack of fusion, undercuts, weld or hook cracks in the longitudinal electric resistance weld seams, etc., if they lie within ±10 degrees of the pipe axis. GE classified anomalies detected within a 0.78 inch-wide band on either side of the longitudinal electric resistance weld seam as "defects adjoining the weld." GE reported detected anomaly depths in four groups/classes: less than 12.5%, between 12.5% and 25%, between 25% and 40%, and more than 40% of the wall thickness. With this tool, anomalies deeper than 40% of the wall thickness of the pipe could not be further quantified because the reflectors (reflected sound) generated from the anomaly would totally saturate the responders. Though the tool may detect reflectors from anomalies shallower than the lowest contractual detection limit of 0.039," these reflectors may or may not be included in the report as an indication by an analyst. Therefore, should these data were included in the report, the confidence of identification of these defects as cracks would be lower than 85% stated in the specification.

GE stated that there was no change in the detection limits in propane compared to other hydrocarbon liquids. Documents provided by GE also include description of various anomaly terms GE used, such as "crack-like" (a planar, two-dimensional with displacement of the fracture surfaces) or "notch-like" (mechanically induced metal loss, which causes localized elongated grooves or cavities) features.

Dixie conducted an excavation program to validate GE's findings and to verify the tool's accuracy. A total of 41 sites were excavated by Dixie to field verify the characteristics and sizes of anomalies reported by GE. At the excavated sites, anomalies were evaluated by visual inspection, magnetic particle inspection, manual ultrasonic and/or by using a phased array ultrasonic technique. As a part of engineering critical assessment, depths of 50 anomaly features reported by crack detection tool were compared with actual field measurements. Comparison showed that 45 of 50 anomaly depth readings reported by crack detection tool were greater than or equal to actual field measurements. GE stated that this indicated with a 90% confidence level that depths reported by crack detection tool were greater than or equal to field depth measurements.

A total of 14,357 features were reported and sized by GE, of which 570 were reported in base metal, 13,274 were reported adjoining the longitudinal seam weld, 494 were reported in the longitudinal seam weld, and 19 were reported in "not-decidable" locations because in certain pipe-joints the location of a longitudinal electric resistance weld seam could not be identified due to the lack of reflectors coming from the longitudinal electric resistance weld seam.

GE conducted an engineering critical assessment to determine severity of the features reported to Dixie. On the basis of their engineering critical analysis, 227 anomalies were identified as "unacceptable," as they were located outside the acceptable level in a failure assessment diagram level-II plot (described below). According to GE, these "unacceptable," anomalies would require further investigation using the failure assessment diagram level III analysis or field excavations, because they could result in pipe failure. Of the 227 "unacceptable" anomalies, 216 were assessed using crack detection tool data, and 11 were assessed using field examination data during the verification digs. Of the 227 "unacceptable" anomalies, 206 were located adjoining the longitudinal seam weld (aw) and the remaining 21 were located in the longitudinal seam weld (iw), or in "not-decidable" locations (nd) as described above.

The 2006 cut-out and metallurgical evaluation program included 7 of the top 8 "un acceptable" features. A total of 21 pipe-joints, of which 15 had not been previously field inspected, containing various anomalies were removed for hydrostatic testing and metallurgical evaluation.

The engineering critical assessment involved several stages, as additional information was obtained, such as measurement of fracture toughness data for the base metal, longitudinal weld and heat-affected zone, field inspection data, re-analysis of the inspection data, etc. The final report was issued on August 23, 2006. GE used an API 579 failure assessment diagram (FAD) Level-II approach to evaluate the acceptability of the detected anomalies. GE stated that the advantage of failure assessment diagram approach was that it used a two-parameter failure assessment – brittle fracture failure and net section collapse (plastic) failure. The ratio of applied stress intensity factor (K) or applied J-integral (J) to materials fracture toughness (Kmat or Jmat) constitutes the vertical axis (Kr) of the failure assessment diagram level-II plot; and the ratio of applied stress to material's plastic collapse stress (e.g., SMYS) constitutes the horizontal axis (Lr) of a failure assessment diagram level-II plot. Based on its Kr and Lr values, if an anomaly were located outside the failure assessment diagram level-II plot assessment line (curve) in the area bounded by the axes, GE would consider it as "unacceptable." However, if it were located in the area inside the failure assessment diagram level-II plot assessment line (curve) and bounded by the axes, it would be considered "acceptable."

Three specimens each for base metal, heat affected zone, and longitudinal seam weld were tested for fracture toughness and the lowest value obtained for each was used for calculating critical anomaly sizes. The unaffected material from a 12-inch pipe-joint that failed during the 2004 hydro-test on the Demopolis-to-Opelika segment of the Dixie system was provided by Dixie to GE for this purpose. GE used the following values to calculate failure assessment diagram level-II plot:

Yield Strength (SMYS) ksi	Tensile Strength (min. API 5L) ksi	Young's Modulus (E) ksi	Fracture Toughness Kc ksi√in (Approximate CVN ft-lb values*)		
			BM	HAZ	Seam Weld
52	66	30,000	111 (50.0)	58.2 (19.1)	54.7(16.5)

* Obtained using Rolfe-Novak correlation. $K_{IC} = 9.35(CVN)^{0.63}$

The Excel spread-sheets created by GE for Dixie for evaluations during crack detection tool verification digs indicated that for the values described in the above table, a flaw as deep as 35% of the wall thickness would be acceptable, and may not need further evaluation because these anomalies may not lead to catastrophic rupture.

At NTSB's request, GE created a similar spreadsheet for 1440 psi operating pressure, but for different fracture toughness values. It indicated that an anomaly ~ 25% wall-thickness deep (~0.1”) by ~ 0.9” long would need further analysis if the material has low fracture toughness value of ~ 4 ft-lb, as it could lead to rupture.

GE identified ruptured pipe-joint as pipe number 5808 and estimated it to be 52.09” long,

For the ruptured pipe-joint, the Ultra Sonic Crack Detection tool captured a total of 33 reflectors (reflected sound), but only 3 met GE’s criteria for an analyst’s evaluation (>0.039 “ deep and > 0.998” long), and were further evaluated. GE reported these indications as:

16-00689: Inclusion-like and was non reportable.
16-00737: Notch-like, 51.43 feet (51’-5. 2”) from the upstream girth weld, approximately 4.6” long, and < 12.5% wall thickness deep.
16-00728: Geometry/deformation feature, 51.85 feet (51’-10. 2”) from the upstream girth weld, approximately 2.8” long.

The last two features were reported situated in the base metal in GE’s final ultra sonic crack detection tool report and were corrected to be situated adjoining the longitudinal seam weld upon review of the data after the November 1, 2007 release; but according to GE’s critical crack assessment evaluation, were not considered anomalies that should require immediate attention or further evaluation because they fell below the failure assessment diagram level-II curve.

Several of the 33 reflectors, which did not meet crack detection tool’s criteria for an analyst’s evaluation were located in the, or adjacent to, the longitudinal seam weld. At NTSB’s request GE provided further details on three of the reflectors that were close to GE’s evaluation criteria described earlier:

Reflector No.	Distance in Feet From the up-stream Girth Weld	Length in Inches	Depth in Inches
16	17.84 (17’- 10.08”)	2	< 0.040
17	19.05 (19’ - 0.5”)	2	< 0.040
18	19.57 (19’ - 6.84”)	< 1	0.040

Calculated distance between reflectors (16, 17) and 18 is approximately 4.25”.

(Applicable Attachments: Appendix III to VIII)

The 2006 Magpie Line Reduction Inspection:

Using their deformation tool (pig), Magpie Systems Inc., (Magpie) a division of T. D. Williamson, Inc., inspected the Hattiesburg-to-Demopolis segment on March 27-28, 2006, prior to the magnetic flux leakage inspection (see next section). Dixie stated that Magpie was selected to conduct In-Line inspection because in 2006 T. D. Williamson, Inc./Magpie was Enterprise Product Company’s (managing partner of Dixie) preferred vendor for magnetic flux leakage and deformation In-Line inspection tools, however, reasons for designating Magpie as preferred vendor were not provided by Dixie. Detection capabilities of Magpie' deformation tool (e.g., dent size and depth, ovality, etc.) were not provided by Dixie.

Magpie reported 10 deformation/dents anomalies in the segment, which were more than 0.25 inches deep, and the deepest dent reported was 0.51" deep. However, one of these ten anomalies was associated with a stopple fitting and was not considered to be an integrity issue by Dixie and was not evaluated further. Additionally, two other reported anomalies were less than 0.25 inches deep, but had metal loss associated with them. These eleven anomalies were inspected and repaired or re-coated as appropriate during the 2006 remediation/rehabilitation program.

The ruptured accident pipe-joint was identified as joint number 58340 in the Magpie report. Magpie reported no geometric anomalies in the ruptured pipe-joint.

(Applicable Attachments: Appendix II, Appendix VI, and Appendix IX)

The 2006 Magpie Metal Loss Inspection:

Typically, a high-resolution axial magnetic flux leakage inspection tool could differentiate metal loss between outside and inside surface of the pipeline[2,3]. Magpie conducted a metal loss inspection of the segment on March 29-30, 2006, using a high-resolution axial magnetic flux leakage metal loss tool. Dixie stated that the objective was to evaluate metal loss anomalies in the pipeline.

Dixie stated that Magpie was selected to conduct an In-Line inspection because in 2006 TDW/Magpie was Enterprise Product Company's (managing partner of Dixie) preferred vendor for magnetic flux leakage and deformation In-Line inspection tools; however, reasons for designating Magpie as preferred vendor were not provided by Dixie. Also, detection capabilities of Magpie' tool (e.g., sizing accuracy such as minimum sizeable depth, confidence, locating accuracy, etc.) were not provided by Dixie.

Magpie stated that neither the deformation tool nor the magnetic flux leakage tool was designed to detect the location of a longitudinal electric resistance weld seam in the pipeline. A total of 758 metal loss anomalies were reported by Magpie, of which 155 involved internal metal loss and 603 anomalies involved external metal loss. The deepest anomaly reported had 68% external metal loss.

Magpie reported that for six metal-loss anomalies, calculated safe operating pressure, using modified ASME B31G standard, would be less than the established maximum operating pressure of 1,454 psig for the segment. These anomalies were evaluated and addressed (e.g., repaired or re-coated as appropriate) during the 2006 rehabilitation program.

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[2] NACE International Publication 35100, "In-Line Nondestructive Inspection of Pipelines," December 2000.
[3] NACE International Standard RP 0102-2002, "In-Line Inspection of Pipelines."

Permanent magnet # 111 was located up stream of the ruptured pipe joint, and was used to identify/confirm the ruptured pipe-joint's number. Magpie detected no metal-loss related anomalies in the ruptured pipe-joint, identified as pipe-joint 58340.

(Applicable Attachments: Appendix II, Appendix VI, and Appendix IX)

Dixie's Future In-Line Inspection Plans:

In their May 6, 2008 response Dixie stated that the company's immediate plan was to inspect all of the 12-inch pipeline segments using Rosen's Axial Flaw Detection In-Line inspection tools and also to conduct hydrostatic test, including spike test, the Hattiesburg-to-Demopolis pipeline segment.

Rosen's Axial Flaw Detection In-Line inspection tool capabilities were provided by Dixie and some of the information is summarized below:

	Length Sizing Accuracy	Width Sizing Accuracy	Depth Sizing Accuracy
General Metal Loss (Body of the pipe)	± 15 mm	± 15 mm	± 0.15 X WT
General Metal Loss (Girth Weld and HAZ)	± 25 mm	± 25 mm	± 0.30 X WT
Axial Slotting* Axial Crack**	± 15 mm n/a	- -	± 0.20 X WT n/a

*   For 25 mm long anomaly length. Minimum crack opening requirement is 1 mm.
** For 25 mm long anomaly length. Minimum crack opening requirement is 2 mm.
Confidence Level: 80%
WT = Wall thickness

(Applicable Attachments: Appendix II)

In-Line Inspection Technology:

The American Petroleum Institute (API) standard 1163, "In-Line Inspection Systems Qualification Standard," published in August 2005, covers various aspects of In-Line inspections, and provides guidelines to operators for selecting appropriate In-Line inspection systems.

NACE International publication 35100 "In-Line Nondestructive Inspection of Pipelines," published in December 2000; and NACE International Standard RP0102-2002, "Standard Recommended Practice: In-Line Inspection of Pipelines" published in 2002; summarizes capabilities of various In-Line inspection tools, such as magnetic flux leakage, ultrasonic, geometry, etc.

A high-resolution axial magnetic flux leakage tool was used in the 2006 In-Line inspection of the Hattiesburg-to-Demopolis segment. Magnetic flux leakage tools are typically used to detect and to size internal and external metal loss, and could be used in both gas and liquid pipelines. Typically, these tools are available for pipelines 6” and above. Some of the typical specifications listed in NACE publication 35100 for high-resolution magnetic flux leakage tools are given below. Also, for comparison, applicable equivalent numbers for standard-resolution magnetic flux leakage tools are given in parenthesis.

Description	Minimum Depth	Depth Sizing Accuracy
General Metal Loss	10% of wall thickness (20% of wall thickness)	± 10% of wall thickness (± 15% of wall thickness)
Corrosion at Girth Weld*	10% of wall thickness	± 10 to 20% of wall thickness

Length Sizing Accuracy: 10 mm (13 mm). Width Sizing Accuracy: 10-17mm
Confidence Level: 80% (80%).
* = Limited detection capability upstream and downstream from girth welds.

Several In-Line inspection companies were contacted to obtain information about their tool capabilities and limitations. Most of the companies that responded could meet or beat the above-mentioned specifications for high-resolution axial magnetic flux leakage tools. In-Line inspection technology continues to evolve. However, from the information that was obtained from the companies that responded to the NTSB’s query, no significant change in the axial magnetic flux leakage tool capabilities (e.g., length or depth sizing accuracy), between 2005 and 2008 was noticed.

GE’s Ultra Sonic Crack Detection tool used 45^0 shear waves ultrasound technique and the smallest anomaly depth and length detection limits were ≥ 0.039”(1 mm) and ≥ 0.984” (25 mm) respectively, with 85% probability of detection**.** GE stated that though some improvements in data analysis capabilities have been made, no significant changes in their USCD tool capabilities have been made since 2005.

ATTACHMENTS

APPENDIX I: 1998 Tuboscope ILI Report. (70+cover sheet)

APPENDIX II: 1. Information Provided by Dixie on May 8, 2008. (3+cover sheet)

2. Information Provided by Dixie on May 6, 2008. (25+cover sheet)

3. Information Provided by Dixie on July 17, 2008. (13+cover sheet)

APPENDIX III: GE UltraScan CD Final Report, Revision 3, July 12, 2006, Sections 1-5. (28+coversheet)

APPENDIX IV: Information Provided by GE on April 30, 2008. (43+cover sheet)

APPENDIX V: Engineering Critical Assessment of USCD Reported Defects and Excavation Findings, Revision 6, August 23, 2006, (72+coversheet)

APPENDIX VI: Final Report - Kiefner & Associates, Inc., February 1, 2008. (10+cover sheet)

APPENDIX VII: Draft Report No. 0270-07-17309, Stork Metallurgical Consultants, Inc., March 30, 2007. (139+cover sheet)

APPENDIX VIII: Excel Spreadsheet Created by GE for Dixie. (3+over sheet)

APPENDIX IX: Magpie 2006 ILI Inspection: Executive Summary Report. (11+cover sheet).